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100 mb temperature forecasts for Concorde

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Summary

Continuity charts of 100 mb temperatures are often used as a forecasting tool but can only give a first assessment. Forecast charts from the operational 10-level numerical model also have certain deficiencies though improvements are expected with a new operational model to be introduced this year. A further method is described for obtaining a 100 mb temperature forecast to meet the needs of stratospheric flights by Concorde aircraft.

1. Introduction

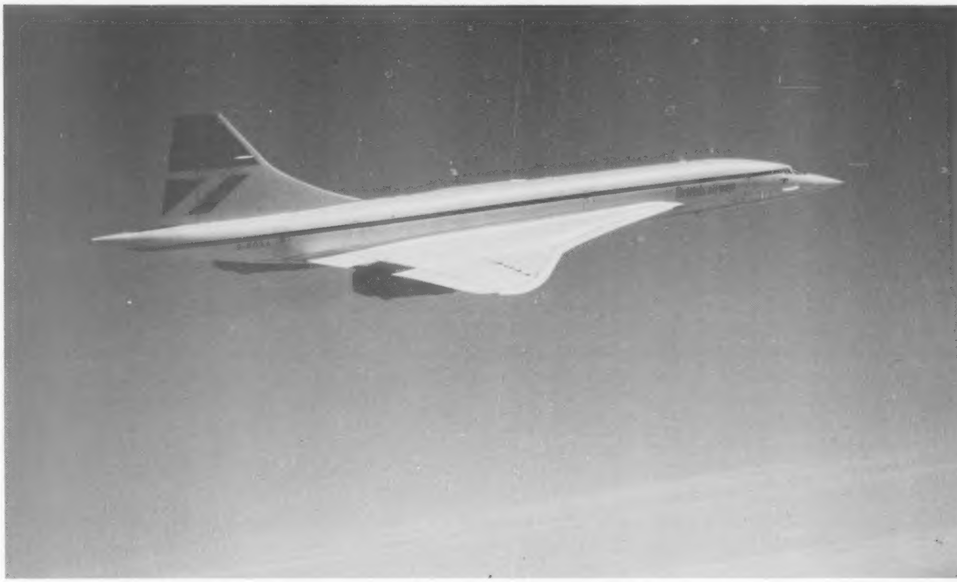
In 1975 Concorde (see Fig. 1) began scheduled transatlantic flights at heights of up to 60000 feet and for a time flights were also made to Bahrain. From the outset a regular service for Concorde was provided by the Central Forecasting Office (CFO) at Bracknell where some other North Atlantic and European flight forecast charts are also prepared as a routine for aircraft at flight levels lower than those of Concorde. The aviation forecaster at CFO was provided with additional computer output to meet the Concorde forecast requirement but it was soon realized that the 100 mb temperature forecasts from the 10-level model were unable to meet the accuracy required by the operators of Concorde, namely British Airways and Air France.

Straightforward temperature continuity charts often give reasonable results, but are not usually reliable in areas of synoptic development. The method described here uses the 300 mb pattern and usually the results agree with, or improve on, the continuity forecast. The method cannot be applied to flow along straight contours, but in that case the continuity forecast is usually good.

2. Requirements of British and French airlines

The two main meteorological aspects which affect the performance of jet aircraft are wind and temperature, efficiency increasing with a decrease of ambient temperature. At the flight level of most

jets the effect of wind is generally more significant but for Concorde, flying at above 50000 feet, the temperature is equally important. For a typical supersonic Atlantic crossing between London and New York the effect of a 1 °C increase in temperature throughout is to increase fuel consumption by about 100 kg. If the ambient temperature is above —51.5 °C the effect is even greater, each 1 °C change making a difference of 350 kg of fuel. This is because the aircraft surface temperature at the normal standard cruise Mach number becomes limiting at —51.5 °C owing to friction, and therefore as the ambient temperature rises above this value, a corresponding reduction in aircraft speed has to be made with a consequent loss of efficiency and increase in fuel consumption.



A British Airways photograph

Figure 1. Concorde in flight.

An example of a 100 mb flight forecast chart is given in Fig. 2 which broadly follows the recommendations contained in the final report of the fifth session of the Commission for Aeronautical Meteorology.* The isotherms are shown by continuous lines and are given in °C as departures from the International Standard Atmosphere (ISA), which at 100 mb is —56.5 °C, at 5 °C intervals. Isotachs are shown by dashed lines at 20 kn intervals (together with areas of MINimum winds) and streamlines of wind direction are shown by arrows. Forecast temperatures at 150 mb (also given as departures from ISA) are supplied in table form for every 10 degrees of longitude along the fixed flight route. Both the route and the table can be seen in Fig. 2. Forecast charts are issued twice daily, at 04 and 11 GMT for validity times of 12 and 00 GMT respectively.

*Fifth session of the Commission for Aeronautical Meteorology. WMO No. 322 (1971).

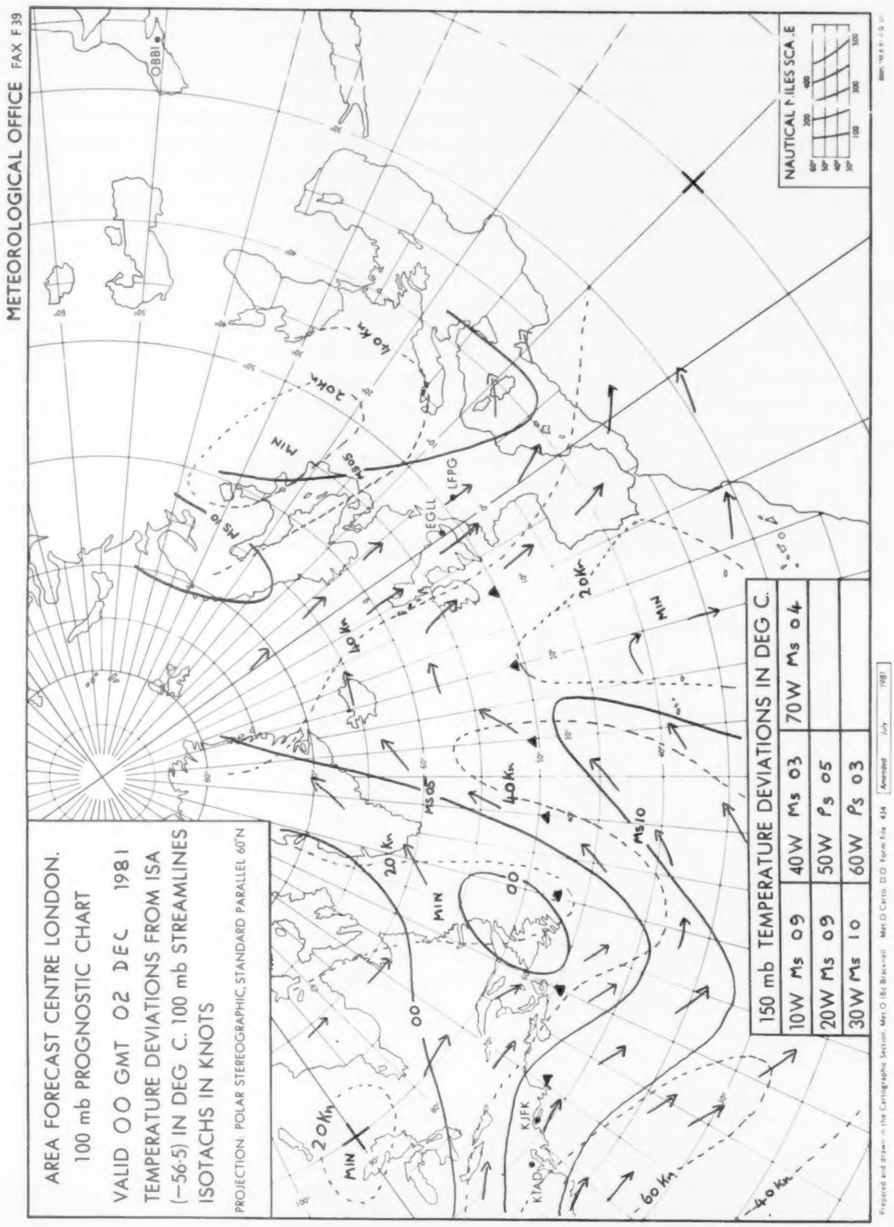


Figure 2. An example of a flight forecast chart for Concorde. (The normal route across the Atlantic has been added, shown by the symbol ▲.)
Positive and negative values are indicated by PS and MS respectively.

3. Concorde reports

Reports of wind speed and direction, temperature, flight level and time, are received regularly from Concorde aircraft (both British and French) and are extremely useful for chart analysis considering the sparsity of observations over the Atlantic. It is not intended in this article to dwell on the accuracy of aircraft thermometry but during the first year of scheduled flights, temperature comparisons between reports from Concorde and those from radiosonde stations (Valentia, Camborne and Ocean Weather Ships) suggested that Concorde temperature reports were slightly too high, and that the error may differ between eastbound and westbound flights. In practice, 2 or 3°C are normally subtracted from the Concorde reported temperature when the 100 mb temperature field is analysed.

4. Computer output

A T+24-hour forecast using data for 00 GMT is available to the forecaster in CFO for the forecast to be issued at 11 GMT; the forecast for issue at 04 GMT, however, is based on a T+24-hour computer forecast using data for 12 GMT the previous day. The computer forecast of isotachs and of wind streamlines are of acceptable standard. This is not so for the 100 mb temperature forecast from the current UK numerical model although the forecast does act as a useful guide to the general pattern of isotherms. The errors arise from the fact that 100 mb is the top level in the current model (note that this will not apply to the new model to be implemented this year). One noticeable feature is that even the analysis is consistently too warm in upper troughs and too cold in upper ridges. An example of this error in an upper trough is seen in Fig. 3 where the geopotential contours have been omitted for the sake of clarity.

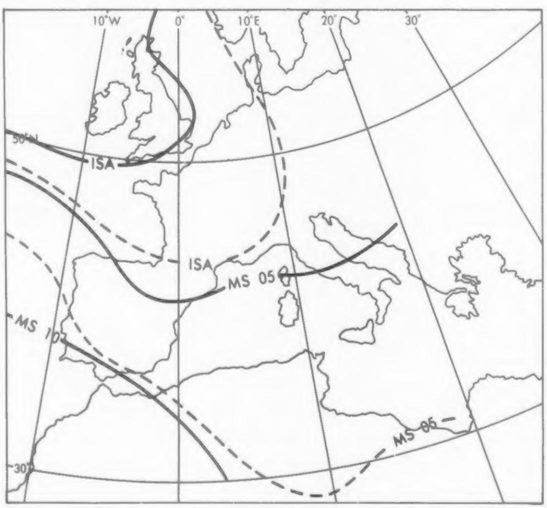


Figure 3. A comparison at 100 mb between the computer analysis (dashed lines) and the analysis of radiosonde temperatures (full lines). Isotherms are given in degrees Celsius as a departure from ISA.

5. A method for obtaining a 100 mb temperature forecast

A first assessment by the forecaster is made using a 12-hourly continuity chart and drawing isotherms as departures from ISA at 5 °C intervals; automatically plotted 100 mb charts in conjunction with the computer 100 mb geopotential forecast chart are also used to provide a preliminary consistency check.

The continuity forecast may be unreliable in areas of synoptic development. An example is given in Fig. 4 which shows little continuity between three 12-hour intervals. However, a reasonable forecast can often be obtained by superimposing the 100 mb isotherms (as departures from ISA) on the 300 mb height contours for the same data time (Fig. 5) and then sketching the isotherms on a computer forecast of the 300 mb height contours while maintaining the same relative positions. Points normally used are just ahead of, at the base of, and just to the rear of troughs; ridges can be dealt with in the same way. Difficulty aries when the upper flow pattern is straight or nearly straight but this means that there is no development taking place and continuity alone will probably suffice. The final assessment is made by comparing the continuity forecast with this second method, tending towards the latter in development areas.

Fig. 6 shows the positions of the 100 mb isotherms relative to the 300 mb geopotential contours after a period of 12 hours from the time of Fig. 5. In this example, the upper trough sharpened as it moved east from Spain to Italy. It can be seen that the −61.5 °C isotherm (i.e. −5 °C departure from ISA) stays between the 924 and 936 decageopotential metre contours at the base of the trough although moving northwards; the −66.5 °C isotherm (i.e. −10 °C departure from ISA) remains close to the 948 decageopotential metre contour. It should be remembered that even though there are plenty of observations the isotherms cannot be accurately placed in the analysis because of observation errors.

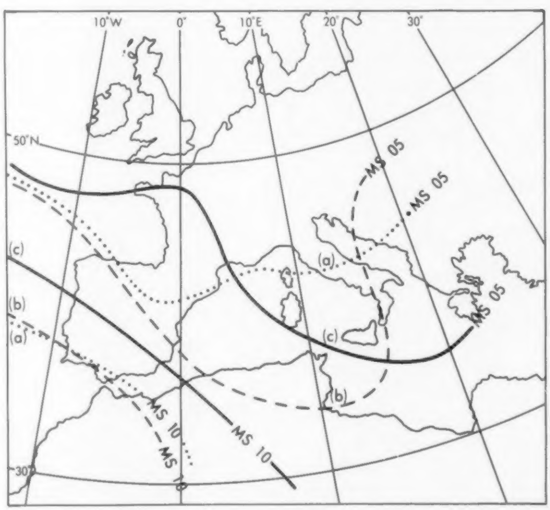


Figure 4. 12-hourly 100 mb isotherms in degrees Celsius as a departure from ISA for (a) 12 GMT 12 December 1981, (b) 00 GMT 13 December 1981 and (c) 12 GMT 13 December 1981.

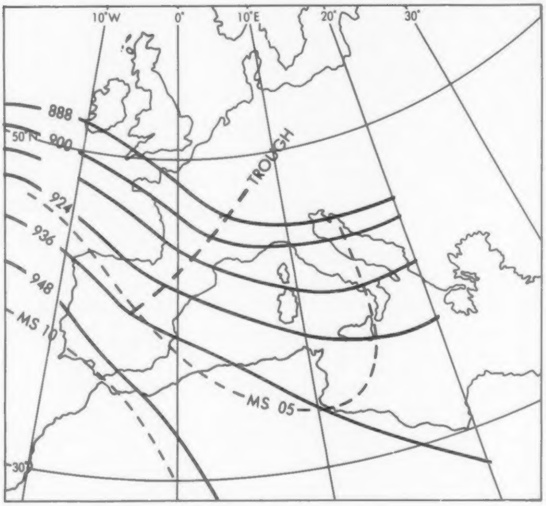


Figure 5. 300 mb contour chart for 00 GMT 13 December 1981. Values in decageopotential metres. Relative positions of the 100 mb isotherms, in degrees Celsius as a departure from ISA, are also shown.

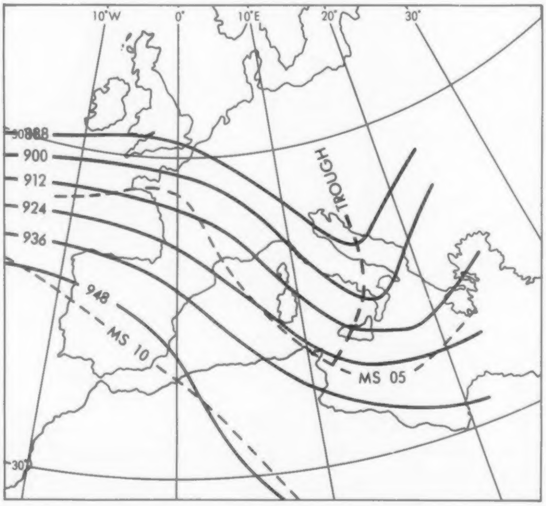


Figure 6. A similar chart to Fig. 5, 12 GMT 13 December 1981.

Although not illustrated, the 300 mb computer forecast for 12 GMT 13 December 1981 agreed reasonably well with Fig. 6 but the trough over Italy was not quite sharp enough and the 924 and 936 decageopotential metre contours were about 2 degrees of latitude further south. Fig. 7 shows the forecast prepared by the method of this section and its improvement over a continuity forecast. Experience has shown that this method considerably reduces the errors that would have been made with a simple continuity forecast.

Note that no useful guidance can be obtained by using the 100 mb geopotential contours in place of the 300 mb contours since the upper flow is considerably smoothed out when temperature changes of only 5°C or so are being dealt with.

6. Completion of the Concorde flight forecast chart (Fig. 2)

The computer handling of the 150 mb temperature is better than that of the 100 mb since the former can be derived directly from the model fields, reducing the error mentioned in section 4. The computer forecast is therefore compared with a 12-hourly continuity chart, and between the two of them a reasonable forecast can be obtained. Streamlines and isotachs are drawn directly from the computer product but with some modification in the light of up-to-date aircraft reports.

7. Concluding remarks

(a) Scheduled times of issue are not ideal. It can be seen from sections 2 and 4 that the forecast for 12 GMT issued at 04 GMT uses a computer 24-hour forecast based on data for 12 GMT the previous day, i.e. with only 8 hours of the forecast period left.

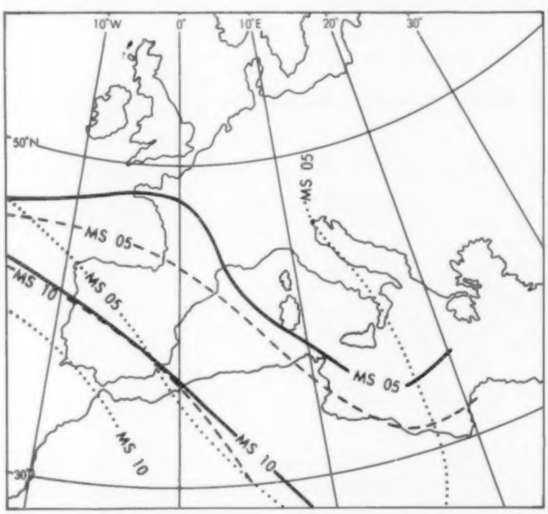


Figure 7. A comparison between the analysis of the 100 mb isotherms (full lines) with the forecasts obtained by continuity (dotted lines) and with the 300 mb contour method (dashed lines) described in section 5. 12 GMT 13 December 1981. Isotherms are given in degrees Celsius as a departure from ISA.

(b) The 10-level model at present in use at Bracknell is to be replaced by a 15-level model extending up to near 20 mb and the quality of the 100 mb temperature fields are expected to improve.

(c) Reports from Concorde over the Atlantic should be a useful source of information for the new 15-level model, provided a detailed check is made of the thermometry to determine corrections to be applied.

(d) A certain amount of continuity is used when analysing the 100 mb temperature chart where observations are sparse, but the analyst is advised to watch carefully any development at 300 mb.

(e) Temperature forecasts at 100 mb can be improved by determining the relationship between the analysed 300 mb geopotential contours and the 100 mb temperatures and extending this using the computer 300 mb contour forecast.

Acknowledgements

I thank British Airways for providing the photograph of 'Concorde in flight' (Fig. 1) and in particular Mr T. C. R. Guest, Manager, Navigation Services, for the information relating to fuel consumption.

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An index of windiness for the United Kingdom

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Summary

An index has been formulated which gives an objective measure of the relative windiness of past months, seasons and years for three regions covering the United Kingdom. The index is based on the standardized anomalies of monthly mean speeds at a number of stations. Daily grid-point surface pressure data have been used to estimate the value of this index for all months from January 1881 to December 1980.

1. Introduction

The increasing degree of interest shown in the potential of wind power as an alternative energy source has led to the Meteorological Office receiving a number of enquiries regarding wind speed frequency distributions at different sites. Although the Meteorological Office holds records of hourly mean speeds in machinable form for over 200 stations in the United Kingdom (UK), many of these records are of less than 15 years' duration and are not homogeneous in time owing to site, exposure or instrument changes. As a result, it is often difficult to analyse the spatial variation of wind speed distributions over the UK.

The Investigations Group of the Climatological Services Branch is addressing this problem by developing stochastic models of time series of hourly mean speeds for various locations in the UK. These models are based on the comparatively short periods for which machinable data exist and it is therefore necessary to know just how representative are the periods from which the models are being derived.

For this reason, and indeed for other applications, there is a need to be able to assess objectively the windiness of a particular period, be it a month, season or year. It appears that no such indicator or index exists for the UK. This is probably because:

(a) Any study of wind speeds at different stations is complicated by the fact that speeds can vary substantially over short distances in the vertical and in the horizontal, particularly at the heights at which speeds for climatological purposes are recorded. The exposure of anemometers in the UK varies from station to station and, although an effective height of 10 m is the recommended standard, many stations have their instruments positioned at other heights; they may be on the tops of buildings, for example.

(b) At any one station there may have been changes in the type of anemograph or changes of site or both. Many stations observing during the 1950s and 1960s replaced a pressure-tube anemograph by a Mk 2 (and subsequently a Mk 4) cup generator anemograph. Work by the present author indicates that Mk 2 and Mk 4 cup generator speeds are on average about 1–2 kn higher than pressure-tube values (Smith 1981). It is also possible that readings from the Mk 5 cup generator, recently installed at several UK stations, are not consistent with those from the Mk 2 and Mk 4. Site changes can also occur quite frequently (for reasons such as the construction of buildings close to the anemometer) and speeds from one site are often not consistent with speeds from another.

Despite these problems, work has been undertaken to devise an index of windiness using stations that appeared to provide reasonably long-period homogeneous records of wind speeds. Indices were determined initially on a monthly basis and then means of successive monthly indices were taken to construct seasonal and annual values. In the second part of this paper a procedure for estimating index values based on surface pressure gradients is described and results given. Estimates have been produced for months from January 1881 onwards, well before anemograph observations become available.

Possible applications of the index are:

(a) to gauge the long-term year-to-year variability of wind speed,

(b) to determine the representiveness of speeds in a specific period relative to speeds from a longer period,

(c) to act as a quality control of mean wind speeds at individual stations, and

(d) to study climatic change.

2. Index values based on anemograph data

2.1 *Stations and data*

A total of 17 stations having data considered to be reasonably homogeneous for the period 1965–79 were selected for the analysis. Their locations are shown in Fig. 1; the regions delineated are discussed later. The distribution of the stations across the country is seen to be fairly uniform. (Unfortunately, there are no suitable stations available to fill the 'gaps'.) With the exception of Benbecula, Leeming and Honington each of these stations has hourly mean speeds recorded each hour of the day for the period 1965–79 with:

Figure 1. Location of the stations and regions used for the derivation of the values of the index.

(a) no more than 170 missing observations in any month,
(b) no recorded change of instrument from a pressure-tube to a cup generator anemograph, and
(c) no recorded site change.

At Benbecula there was a site and instrument change on 1 April 1965. For Leeming and Honington data are available only from December 1965 and October 1969 respectively.

Monthly mean speeds were determined for all stations for each month from January 1965 to December 1979. Missing values for Leeming were estimated from Ringway data. For Honington, data from Mildenhall (only 25 km from Honington) were used to derive estimates for the period 1965–1968, with Elmdon speeds used for estimating values for January – September 1969.

2.2 *Formulation of index*

An index of windiness based solely on the absolute magnitude of the wind speed at different stations would be unsatisfactory because its value would depend greatly on the locations and sites of the stations chosen. The index is therefore based on the standardized anomaly of each month's speed relative to a long period monthly average.

The average and standard deviation of the monthly means from 1965 to 1979 were calculated for each of the 17 stations and for each month of the year. The difference between the mean speed for an individual month and the long period average for that month was then determined and expressed as a proportion of the standard deviation. So, for each station, a series of monthly standardized anomalies, y_i, were obtained, given by

$$y_i = \frac{x_i - \bar{x}}{\sigma} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (1)$$

where x_i is the mean for month *i*, and $\bar{x}$ and σ the 1965–79 average and standard deviation of the individual means for the month in question.

The distributions of y_i have zero mean but are somewhat positively skewed because positive anomalies of monthly mean speeds tend to be larger in absolute value than negative anomalies.

The values of y_i for each station are shown for January 1974, a windy month, and for August 1976, a month with below-average speeds, in Figs 2(a) and 2(b) respectively.

It was observed, quite frequently, that the standardized anomalies varied considerably across the country in a consistent fashion (although not in Figs 2(a) and 2(b)). It therefore seemed appropriate, for the purpose of formulating a windiness index, to divide the UK into regions. In general the spatial correlation of wind speed is greater in an east–west direction than in a north–south direction, owing to the predominantly zonal movement of synoptic features at mid-latitudes. A north–south division of regions was therefore chosen and the regions are shown in Fig. 1. The south region contains five stations and the others, six stations each.

The final step in deriving the index *I* was, for each region and for each month, to take the arithmetic mean of the y_i values over the stations within the region. This averaging reduces the effects of any inconsistent values in a region, such as the rather low values for Fleetwood and South Shields observed in Fig. 2(a), and should produce a quantity which is more representative of the region as a whole than could be obtained from any single station.

Winter (October to March), summer (April to September) and annual (January to December) indices were also obtained for each region by averaging the monthly indices over the appropriate months, then

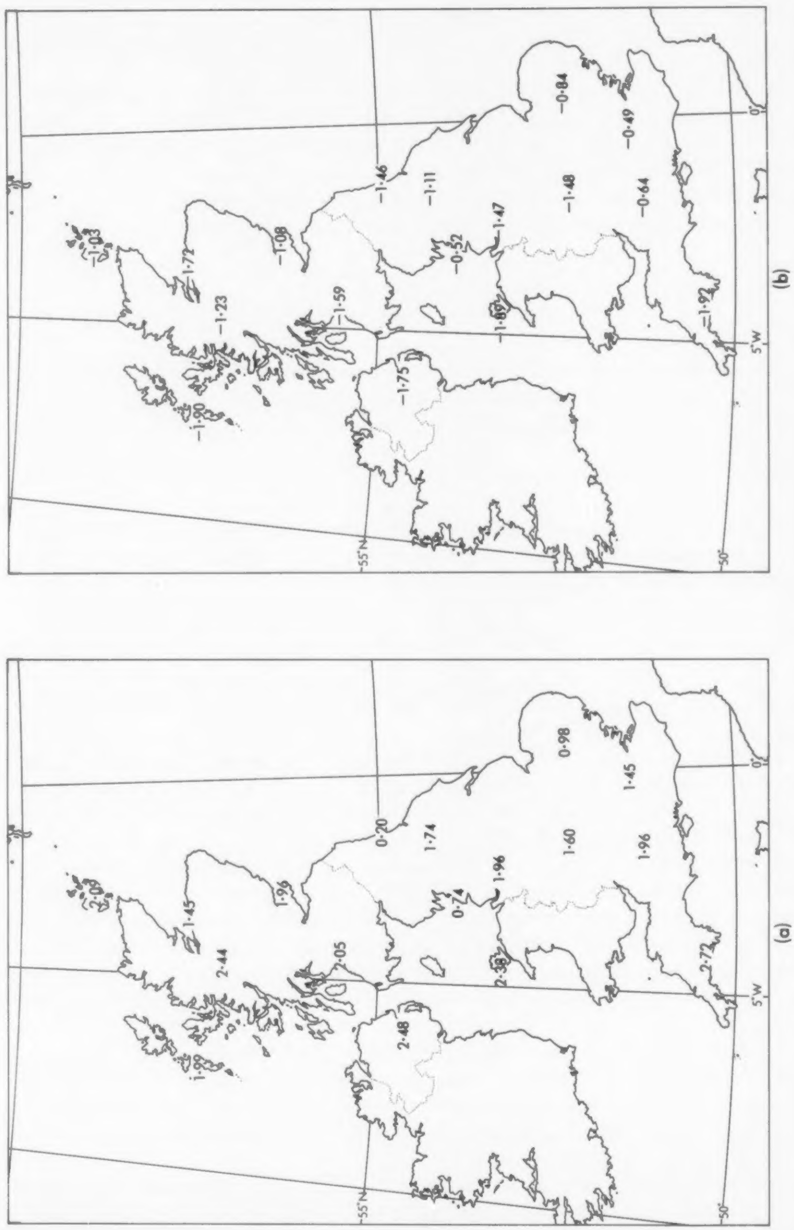

Figure 2. 'Standardized anomalies' of monthly mean wind speeds (see text) for (a) January 1974 and (b) August 1976.

expressing each value as a proportion of the standard deviation of the derived averages for the season (or year) over the period 1965–79*.

Note that it is possible to derive estimates of the absolute monthly mean speeds, say, for a particular site from the corresponding regional monthly indices if the 1965–79 means and standard deviations for the site are known or can be estimated.

2.3 *Results*

In what follows, I_n, I_c and I_s will denote the indices for the north, central and south regions respectively, I the collective term for these indices and 'quiet' will be used as an antonym of 'windy'.

I_s is plotted for January and July as the full line in Fig. 3. (The 'estimated' values also shown in this and the next two figures are explained in the next section.) For January, a noticeable feature is the run of windy months between 1974–76. The graph for July indicates that, for the south, Julys between 1968 and 1973 inclusive were quiet except for 1970.

I_n, I_c and I_s are shown for winter, again as the full lines, in Fig. 4. Values are plotted against the year in which January–March fell. Taking the three regions together, the windiest winter was 1966–67 and the quietest, 1976–77.

Annual indices are plotted in Fig. 5. The year 1967 was the windiest with 1971 and 1976 the quietest.

3. Estimated index values based on surface pressure gradients

3.1 *Preliminaries*

It was not feasible to produce index values based on anemograph data for years prior to 1965 because the number of stations with homogeneous data extending from before 1965 to at least 1979 decreases rapidly as one goes back in time. The possibility of using daily surface pressure values (which are available from 1 December 1880 onwards) to derive wind speeds and hence indices was therefore explored.

The Synoptic Climatology Branch of the Meteorological Office have produced time series of daily southerly and westerly 'flow indices' for various grid points around the British Isles, obtained from surface pressure gradients at midnight or midday. From these indices the wind speed W_j at the jth grid point can easily be determined. Details of the procedure are given in the Appendix. W_j is equivalent to geostrophic speed at 55°N 5°W and approximately geostrophic speed at other grid points. Speeds from six grid points (see Fig 6) were used to estimate I_n, I_c and I_s.

Monthly means of W_j were produced for these grid points from January 1881 to December 1980 by averaging the daily values. Unfortunately the data are not homogeneous because the grid-point surface pressures have been obtained from different sources based on different analysis schemes—the sources are listed in Benwell (1976). Jenkinson and Collison (1977) suggest adjustment factors to homogenize high daily values of W_j. They advocate adding 9% to observations in the periods 1899–1939 and 1949–59 and 25% to values in 1960–65. A comparison of annual means of W_j against annual values of I_s for 1965–80 and a time series plot of annual W_j indicated that the addition of 25% for 1960–65 speeds is probably too high for the present application. A correction of +20% was therefore used instead, with +9% still applied to the two earlier periods. These adjustments are rather speculative in view of the lack of supporting data, especially for the earlier years, but they are considered to be the best available.

*Index values have now been calculated for each month, season and year for 1980.

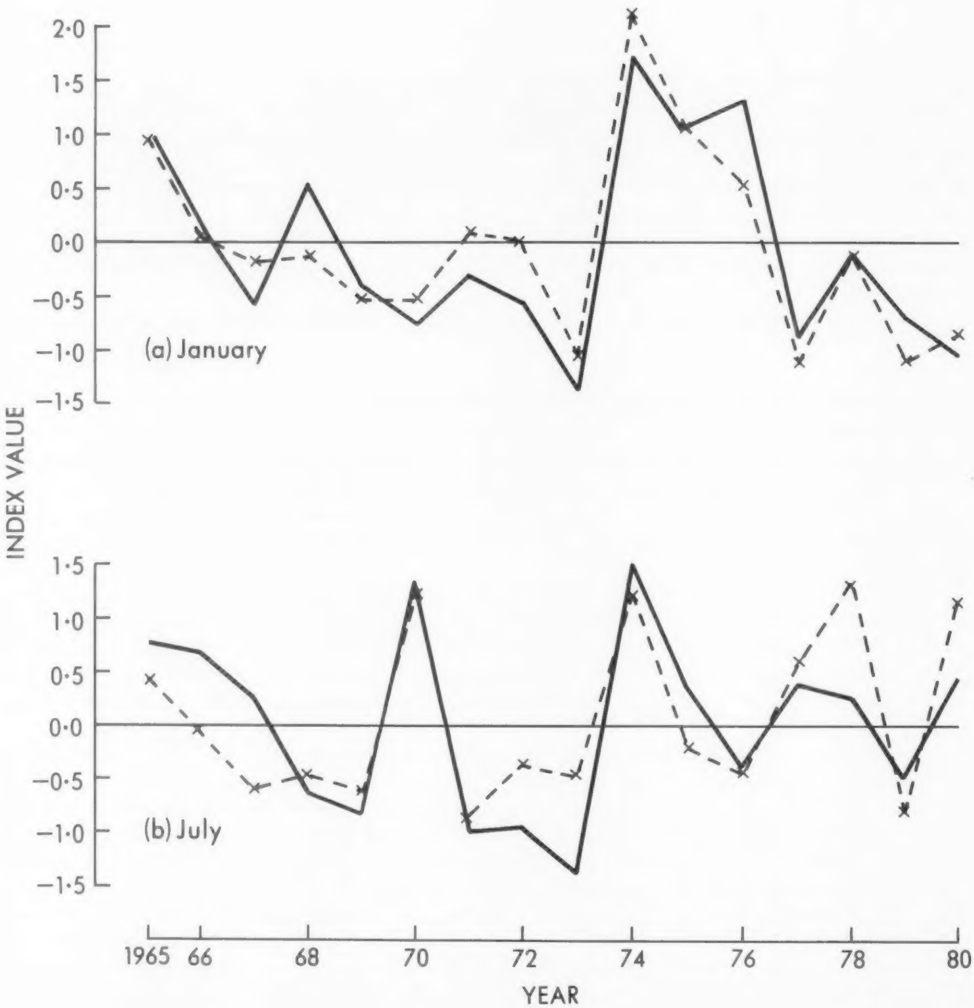

Figure 3. Actual (full lines) and estimated (dashed lines) values of the index of windiness for January and July, south region.

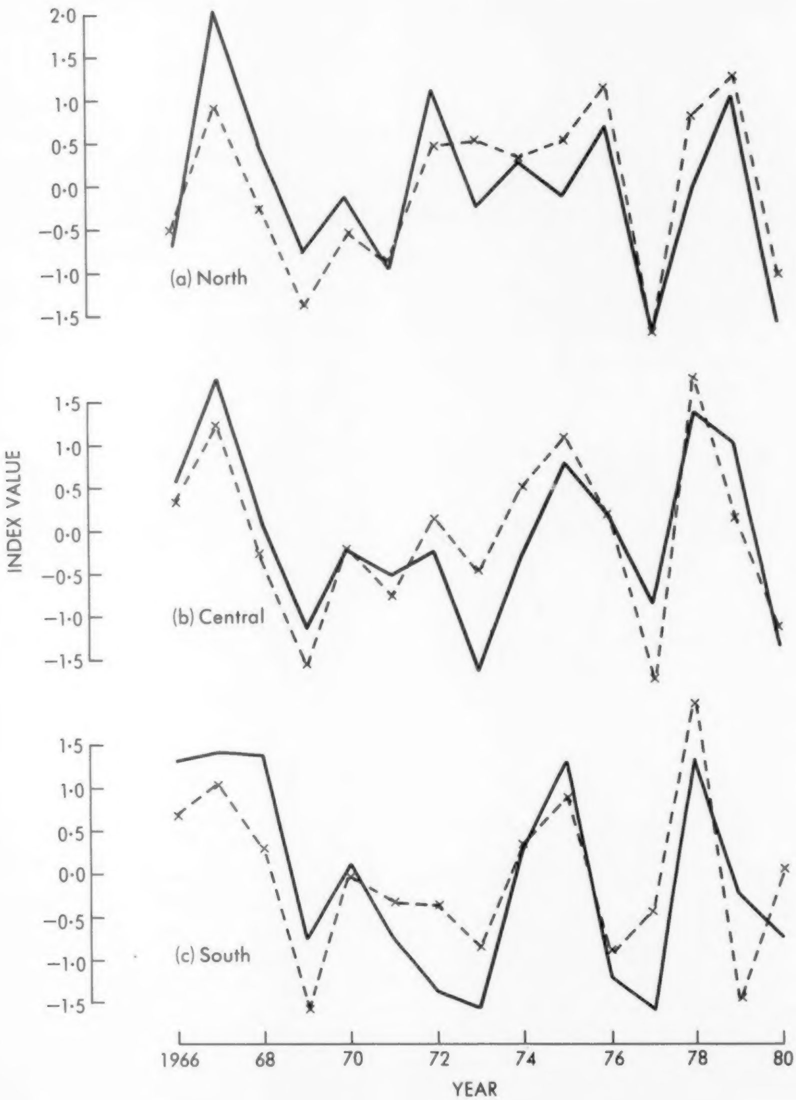

Figure 4. Actual (full lines) and estimated (dashed lines) values of the index of windiness for winter (Oct.–Mar.), all three regions.

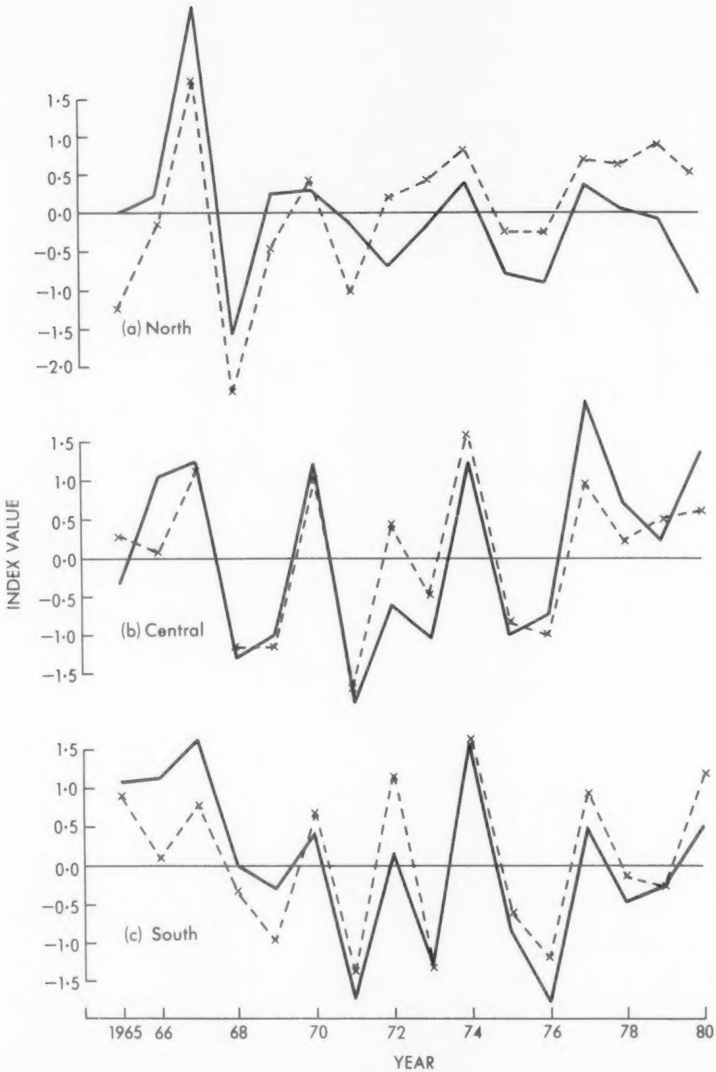

Figure 5. Actual (full lines) and estimated (dashed lines) values of the index of w‑ndiness for the year, all three regions.

Means and standard deviations of adjusted monthly W_j were calculated for each month of the year and over the same period for which I had been determined, namely 1965–79. Monthly standardized anomalies (S_j) were then produced using the form of equation (1) for each grid point from 1881 onwards.

3.2 *Estimation procedure*

It was next required to estimate I_n, I_c and I_s using the six grid point S_j as predictors. To obtain the regression equations the stepwise regression computer program BMDP2R, available in the BMDP statistical package (University of California 1979), was run on 192 monthly values—January 1965 to December 1980 inclusive—of I_n, I_s and I_c separately with corresponding grid point S_j.

Figure 6. Location (X) of grid points used for the estimation of the values of the index.

The resulting regression equations are presented in Table I. The BMDP 'all possible subsets regression' program (BMDP9R) was applied to subsets of the sample of 192 cases to study the mathematical stability of the equations. Results were found to be satisfactory.

The standard error of the residuals and the squared multiple correlation coefficient are also shown in Table I. The magnitude of the latter, representing the fraction of the variance of I explained by the regression, indicates that the estimates are reasonable approximations to I_n, I_c and I_s.

The variance of the estimated indices (which will be denoted by $\hat{I}_n$, $\hat{I}_c$ and $\hat{I}_s$) was observed to be about 15% less than the variance of the actuals. This arises from the smoothing inherent in the regression equations. $\hat{I}_n$, $\hat{I}_c$ and $\hat{I}_s$ were therefore multiplied by appropriate factors to restore the original variances.

Table I. *Regression equations for estimates of monthly indices*

Region	Equation	Standard error of residuals	Squared multiple correlation coefficient
North	$\hat{I}_n = 0.25S_2 + 0.63S_3 - 0.13S_6$	0.39	0.77
Central	$\hat{I}_c = -0.11S_1 + 0.69S_3 + 0.18S_6$	0.39	0.76
South	$\hat{I}_s = 0.41S_5 + 0.34S_6$	0.48	0.69

S_j represent monthly standardized speeds at grid point j where
$j = 1$ corresponds to 60°N 5°W
$j = 2$ corresponds to 60°N 5°E
$j = 3$ corresponds to 55°N 5°W
$j = 5$ corresponds to 50°N 5°W
$j = 6$ corresponds to 50°N 5°E

Finally seasonal and annual estimates were determined from the monthly values by averaging and standardizing, as carried out for the actual indices.

3.3 *Comparison between estimated and actual index values*

Fig. 3 displays I_s and $\hat{I}_s$ for January and July between 1965 and 1980. The standard error of the estimates is greater for July and in general there is a slight tendency for errors to be larger for the summer months compared to winter months. Also the correlation between monthly indices for different regions is in general lowest in the summer months. These findings probably arise from the fact that in summer, winds are lighter and pressure systems less intense leading to a weaker relationship between pressure gradients and surface wind speeds and a higher spatial variation. The plots visually confirm that $\hat{I}_s$ is a reasonable indicator of I_s.

Winter and annual values of the actual and estimated indices are shown for all three regions in Figs 4 and 5. Again the year-to-year variation in the actual values is well reflected by the movement of the estimated indices. There does appear to be a bias in the estimates, particularly those for the north, in that the estimates tend to be lower, relative to the actuals, before 1972 than in subsequent years. This may arise from a change in the analysis of surface pressures around 1972.

4. Results

The estimated index values need to be treated with some caution, not only because they are estimates and are therefore subject to error but also because it is probable that the effects of the inhomogeneities present in the surface pressure data have not been completely removed by the adjustments made to W_j. However the estimates should provide a useful guide to the relative windiness of a month, season or year.

Annual means of the estimated indices are plotted for the different regions in Fig. 7 together with the seven year running mean calculated using 1/64, 6/64, 15/64, 20/64, 15/64, 6/64, 1/64, as 'binomial' weights. The windiest periods are the 1920s and 1950–64. The quietest periods are 1930–47 for the north and central regions and the late 1960s onwards for all regions. The last-named is of particular interest, of course, because most of the available anemograph data relate to this period. The values for a number of years show large variations between regions e.g. 1882, 1898, 1965 and 1973.

Table II gives the windiest and quietest months, seasons and years for each region over the period 1881–1980 based on estimated values throughout. The only month to be the windiest in all regions is February 1903; note also that the following month, March 1903, is the windiest March for two regions. Examination of daily weather summaries for February and March 1903 indicated that during these months a succession of vigorous depressions passed over or close to the British Isles. The distribution of windiest months through the 100 years is fairly even. For the quietest averages, June 1895 and December 1890 are extreme months for all three regions. Study of weather summaries revealed that the weather at these times was dominated by high-pressure systems. The most recent years have given several low extremes, a feature which is particularly noticeable on the seasonal and annual time scale.

Finally, to present the indices for all months together in a convenient form the monthly values for each region have been averaged and are shown in Table III. Again estimated values have been used throughout. Occasions when the range of values I_n, I_c and I_s exceed 1.5 are marked with an asterisk; for these months the variation in windiness across the UK is thus relatively large. The windiest month (relative, of course, to the 1965–79 mean for that month) is seen to be February 1903 and the quietest months are the Novembers of 1942, 1945 and 1958. One interesting feature of the values is the small number of Augusts with below average speeds between 1881 and 1930.

Table II. *Windiest and quietest monthly, seasonal and annual averages for the period 1881–1980*

	North		Central		South	
	Windiest	Quietest	Windiest	Quietest	Windiest	Quietest
Jan.	1916	1881	1916	1881	1937	1953
Feb.	1903	1942	1903	1917	1903	1891
Mar.	1967	1929	1903	1929	1903	1946
Apr.	1949	1974	1947	1974	1947	1956
May	1956	1977	1964	1940	1972	1978
June	1923	1895	1923	1895	1882	1895
July	1928	1968	1954	1955	1954	1901
Aug.	1940	1947	1891	1937	1891	1937
Sept.	1950	1894	1950	1972	1954	1971
Oct.	1934	1914	1934	1937	1891	1978
Nov.	1888	1882	1888	1942	1881	1934
Dec.	1974	1890	1974	1890	1929	1890
Winter (Oct.–Mar.)	1881–82	1976–77	1902–03	1887–88	1902–03	1952–53
Summer (Apr.–Sept.)	1919	1968	1923	1971	1882	1976
Annual	1923	1968	1923	1971	1882	1971

5. Future calculation of index values

Already since 1980 Kew Observatory has closed and the Mk 4 anemometer at Elmdon has been replaced by a Mk 5 and moved to a different site. Inevitably there will be further closures, changes of site or changes of instrument at other stations used in the calculation of the windiness indices, reducing the usefulness of anemograph data for the estimation of windiness for periods after 1980. Barometer readings from individual stations could be used instead but owing to non-availability of data it is not possible at present to derive windiness indices extending very far back in time using such values. The daily grid-point surface pressures may therefore be the most satisfactory indicators of windiness for future climatological studies on a large scale. This is with the proviso that any inhomogeneities in time introduced into the surface pressure data by alterations to the Meteorological Office numerical analysis scheme (from which surface pressure values are currently obtained) are insignificant or can be allowed for.

Table III. *Monthly indices averaged over the three regions for the period 1881–1980*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1881	−1.5	−0.4	0.0	0.4	0.1	1.3	0.5	1.3	−0.9	0.7	2.6	−0.4
1882	−0.1*	0.8*	0.6	0.3	0.1	1.8*	1.2*	2.0*	−0.6	−0.3*	−0.4*	−1.0
1883	0.8	2.1	0.4	0.0	0.5	−1.1	0.4	0.8	0.2	0.8	0.6	−0.2
1884	1.0	2.3	0.1	−0.9	0.8	−0.8*	−0.2	0.0	0.4	0.8	−0.9	0.4
1885	0.1	1.2	−0.4	−0.1	0.6	0.1	−0.4	0.4	0.7	0.6	−0.6	−0.3
1886	0.2	−1.2	0.3	0.5	−0.2	0.3	1.0	0.8	0.3	0.1	−0.6	−0.3
1887	0.0	0.5	−1.1	−0.3	0.2	−0.8	0.6	0.6	−0.2*	−0.1	−1.1	−0.3
1888	−0.7	−0.8	−0.4	0.4	1.2	0.1	0.2	1.2	−1.2	−0.2	2.7	−0.5
1889	−0.7*	1.6	−0.6	0.3	−0.7	−1.4	−0.3*	1.6	−0.2	−0.4	−1.0*	−0.2
1890	1.5	−0.6	0.3	0.0	0.3	1.2	1.2	0.9	0.4	0.1	−0.1	−1.7
1891	−0.3	−0.8*	0.3	−0.8	0.2	0.9*	0.3	2.7	1.3	1.6*	−1.3	0.6
1892	0.4	0.6	−1.0	−0.8	0.1	0.1	0.2	0.8	0.8	−0.4	−0.5	−1.0
1893	−0.7	0.8	−0.4	−1.3	−0.3	−1.2	0.0	1.3	0.2	−0.3	−0.1	0.7
1894	1.3	2.7*	0.3	−0.5	0.5	0.1	−0.2*	1.1	−1.5	−1.2*	0.8	0.4
1895	−0.8	−0.4	−0.3	0.1	−0.4	−2.1	0.2	0.8	−0.6	−0.4	0.6	0.4
1896	−0.8	−0.2*	0.5	0.0*	−0.8	−0.5*	−0.4	0.9	1.0	0.2	−1.5	−0.4
1897	−0.4	0.2	0.9*	0.5	1.4	0.0	0.2	1.7*	0.4	−0.4	−1.1	0.5
1898	−0.6*	2.2*	−0.5	0.1	0.4	0.3	0.0	1.5	−0.3	0.0	−0.7	1.0
1899	0.0*	0.3	−0.8	0.4	−0.6	−1.7	−0.2	0.3	0.8	−0.1	0.9	−1.2
1900	0.3	−0.7	−0.9	−0.3	0.9	0.1	−0.3	0.0	−0.2	−0.3	−1.2	0.8
1901	1.0	−1.7	0.3	0.5	−0.5	1.2*	−1.1*	0.8	0.8	−0.1	−1.2	0.3
1902	0.1	−0.2	−0.2	0.0	0.9	0.8	−0.1	−0.4	0.0	−0.5	0.6	0.6
1903	1.0	3.5	2.0	0.3	0.3	0.4	0.0	1.8	1.3	0.3*	−0.3	−0.7
1904	0.9	0.2	−0.4	1.8	0.6	1.7	−0.2	0.6	0.0	−0.5	−1.0	−0.8
1905	1.0*	1.1	0.5	0.2	−0.2	−0.1	−0.8*	0.3	0.6	−0.3	−1.1	0.3*
1906	1.4	1.0	0.7	−0.3	0.7	−0.5	0.1	0.5	−1.0	−0.3	0.1	0.1
1907	0.2	1.1*	0.4	0.2	0.6	2.1	−0.4	1.3	−0.9	−0.7	−1.9	0.2
1908	0.5	1.7	−0.3	−0.2	0.4	0.1	−0.4	0.9	0.6	0.1	0.2	0.0
1909	0.5*	0.0	−0.7	0.2	0.5	−0.4	1.3	0.6*	−1.1	1.3	−1.3	−0.5
1910	0.8	2.3	−0.1	0.0	0.3	−0.6	0.5*	−0.1*	−0.9	0.0	−0.9*	0.5
1911	−0.3*	1.4	−0.1	0.7	−0.1	1.0	0.2	0.8	−0.2	−0.2*	1.3	0.8*
1912	−0.5	0.3	0.6*	0.2	−0.7	0.6	0.0	0.6*	0.4	0.5	0.0	1.1
1913	0.9	0.5	1.5	1.1	0.9	0.8	−0.4	−0.7	−0.5	−0.4	1.7	−0.1
1914	0.0	1.6	0.6*	0.9	0.0	−0.3*	0.2	0.2	0.5	−1.7	0.5	0.4
1915	−0.2	1.1	−1.0	0.5	−0.5	−1.5	0.0	−0.5	−0.6	−1.0	−0.5	−0.8*
1916	1.9*	1.8	−0.2	0.5	−0.8	1.6	−1.1	0.2	0.2	1.3	0.9	−1.3
1917	−0.7	−1.7	−0.1	−0.4	−0.2	−0.1	−0.6	1.2*	0.4*	1.1	0.3*	−0.7
1918	−0.1	2.7*	−0.8	−1.1	−0.7	0.6	0.2*	0.8*	0.8	0.8	−0.5	0.1
1919	−0.4	−1.2	−0.8	0.6	0.5	2.4*	−0.1	1.3*	0.8	−0.4	−0.3	1.1
1920	1.3	2.0*	0.6	0.0	0.8*	0.6*	0.7	0.1	−0.3	−0.2	0.5	−0.7
1921	0.8	−0.7	1.6	−0.1	0.0	0.4	−0.2	0.6	−0.4	−0.9	−0.1	1.1
1922	0.9	1.4	−0.3	−0.8	0.8	0.2*	1.0	0.6	−0.4	−0.5*	−0.7	0.1
1923	0.5*	1.9	−1.0	0.3	0.6	2.8*	0.5	2.0	0.7	1.7	−0.3	−0.3
1924	0.2	0.1	−1.1	−0.5	0.0	−0.4	0.5	1.3	0.9	−0.5	−0.8	1.0
1925	0.7	1.4	−0.5	0.3	0.6	0.8*	−0.3	0.6	0.8	0.1	−1.5	−0.1
1926	0.3	1.2	0.3	0.0	0.2	−0.5	0.1	1.6	−0.5	−1.0*	−0.1*	−0.8
1927	0.7	−0.3	0.1*	0.9	−0.3	0.7	−0.1	1.1	−0.1	−0.5*	0.4	−0.1
1928	1.6	2.6	−0.2	0.4	0.1	1.3	0.7*	0.4	−0.4	0.8	1.6	−0.5
1929	−1.3	0.2	−1.4	−0.6	−0.1	1.1	−0.2	0.8	−0.3*	0.5	2.1	1.9*
1930	0.8	−1.4	−1.0	0.3	−0.3	0.0	0.1	1.4*	−0.4	1.4	−0.2	−0.8

Note. Months where the range of values for the three regions exceeds 1.5 are marked with an asterisk.

Table III.—*continued*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1931	−0.6	1.1	−0.4	0.3	0.3	−0.4	0.7*	0.7	−0.9	−0.1	0.6	−0.1
1932	1.1	−0.6	−0.9	1.2	0.2	−1.3	0.5	−0.8	−0.1	0.0*	0.3	0.6
1933	0.0	0.8	0.4	−0.4	−0.7	0.0	0.2	0.9*	−1.5	0.3	−1.8	−1.3
1934	1.2	0.0*	−0.2	0.5	0.7	−0.8	−0.4	1.2	1.5	1.8	−2.1*	0.2
1935	−0.5	1.9	−0.5	−0.4*	−0.5	0.7	0.3	−0.5	0.9*	1.6	0.8	−1.0
1936	−0.7	−0.3	−0.8	−0.1	0.1	−1.2	0.7*	0.0	−1.0	0.8	−1.0	1.0
1937	2.1	1.3	−0.7	−0.3	−0.9	0.4*	−0.5	−1.5	0.2	−1.7	−2.1	−1.3
1938	1.0	1.1	0.5*	−0.3	−0.1	2.2	0.0	−0.3	−0.5	1.5	1.8	0.3
1939	−0.3	1.9	0.2	0.2	−0.5	1.0	1.0*	−0.6	−0.7	0.0	1.8	−1.2
1940	−1.3	−0.6	−0.1	−0.1	−1.4	−1.0	−0.3*	1.7*	0.8	0.0	0.4	−0.4
1941	−1.1	0.5	−0.9	−0.1	−0.3	−0.6*	−0.6	1.8*	−0.8	0.0	0.1	−0.3
1942	−0.4	−1.9	−0.6	0.8*	0.4	−1.0	0.9	1.4	0.3	0.2	−2.5	0.6
1943	0.2	1.9*	−0.4	1.4*	0.4	0.8*	0.2	1.1	0.5*	0.5	−0.3	−1.1
1944	0.8	0.2	−1.1	−0.1	0.3	1.0	−0.4	−0.2	0.0	−0.2	0.0	−0.2
1945	−0.9	1.9	−0.1	−0.1	0.2	1.6	0.2	−0.3	0.1	−1.0*	−2.5	−0.2
1946	0.7	1.1	−0.9	−0.2*	0.3	1.2	0.7	0.2	1.2	−1.0	0.0*	−0.6
1947	0.3	0.1	−0.6	2.3	0.0	0.7	−0.3	−1.3	−0.1	−0.9	−0.1	−1.0
1948	−0.2*	0.7	−0.1	0.0	−0.8	0.9*	0.9	0.5	1.1	0.3	−0.5	0.4
1949	1.0*	2.2*	−0.5	1.9*	−0.2	−1.0	−0.6	0.5	−0.6	0.7	0.5	0.7
1950	−0.1	1.6	−0.2	1.1	0.0	0.0	0.5	1.9	2.2	0.5	0.0*	−0.9
1951	−0.2	0.3	−0.5	0.9	0.3*	−0.4	−0.4	1.9	0.8	−0.2	1.1	0.9
1952	0.6	−0.2*	0.3	0.2	−0.1	0.6*	0.3	0.2	0.7	1.0	−1.7	−0.1
1953	−1.1*	0.4	−0.7	−0.5	0.0	−0.5	1.0*	1.2	0.7	−0.3	1.2*	−0.7
1954	0.3	0.1	−0.1	0.0	0.8	1.0	1.9	0.7	1.7	0.6	0.7	1.3
1955	−0.7	−0.5	−0.9	0.2	0.9	0.9*	−1.2	−0.4	0.9*	−0.5	−1.2	0.3
1956	−0.5	−1.1	1.0	−1.5	1.2*	1.5	0.5	0.2*	0.2	0.4	1.0*	0.8
1957	1.4	0.1	0.1	−0.1	0.1	−1.0	0.1	1.1	1.0	0.5*	−1.0	0.1
1958	0.3	0.6	0.0	0.3	−0.3	−1.0	−0.3	0.9	0.5	0.3	−2.5	−0.8
1959	−0.7	1.2*	0.0	0.4	−0.4	1.8	−0.2	0.4	−1.2	1.1	−0.1	0.6*
1960	−0.7	0.2	0.3	1.3	0.2	0.5	0.6*	−0.3	−0.3	−0.9	0.5*	−0.6
1961	−0.1	2.0	0.5*	−1.1	0.3	0.9*	0.4	2.3	0.5	1.2	−0.8	−1.0
1962	1.1	2.8*	−1.1	0.1*	0.5	1.9	−0.2	1.7	0.1	−0.1	−1.8	0.2
1963	−0.8	−0.4	0.6	0.1	1.3	0.5	−0.1	0.1*	0.5	1.5	−0.7*	−0.4
1964	−0.2*	1.1	−0.3	0.5	1.5	0.8*	1.1	0.4	0.1	−0.7	0.2	−0.1
1965	0.4	−0.4	−0.8	0.2	0.3	0.8	−0.3	1.0	−0.4	−0.1	−0.3	−0.1*
1966	−0.3	0.7	0.3	0.4*	0.6	−0.3	0.3	−0.2	−0.6	−1.3	−0.3	0.7
1967	−0.3	1.6	1.8	0.5	0.8	−0.1*	0.0	−0.3	−0.2	1.7	−0.9	−0.3
1968	−0.1	−1.1	0.6	−0.4	−0.7	−0.4	−0.9	0.0	0.1	−0.4	−0.4	−0.7
1969	−0.6	−0.5	−0.8	0.3	−0.7	−0.5	0.3*	0.5	−0.5	0.0	−0.2	−0.7
1970	−0.5	0.8*	−0.1	0.6	0.4*	−0.3	1.4	−0.3	0.6	0.7	−0.2	−0.7
1971	−0.4	−0.2	−0.8	−1.2	−0.7	−0.1	−0.9	−0.1	−1.2	0.3	0.1	0.0*
1972	0.1	0.0	−0.2	0.7*	1.1	1.7	−0.7	0.3	−1.4	−0.3	0.0	0.9
1973	−0.8	0.4*	−0.7	0.5	0.6	−0.1*	−0.5	−0.1	−0.6	−1.2	0.4	0.1
1974	2.0	0.5	−0.9	−1.8	0.5	0.4	1.0	0.5	1.1	0.2	−0.2	1.9
1975	1.2	−0.5	−0.8	0.3	−0.2	−0.1	−0.3	−1.1	0.6	−0.2	−0.4	−0.4*
1976	1.1	0.3	0.1	−0.3	0.3	−0.7	−0.4	−1.3	0.0	0.0	−0.9	−1.3
1977	−0.7	−0.5	0.5	1.2	−0.9	−0.4	0.2	−0.5	0.9	1.2	2.1	0.1
1978	−0.1	−0.8	0.8*	−0.8	−1.4	0.6	0.9	0.4	1.0	−0.6*	0.7*	0.0
1979	−1.0	−0.3*	1.2	−0.2	−0.1	−0.6	−0.1	1.0	0.6*	0.0	0.4	0.4
1980	−1.2	−0.8	−0.3	−0.3	−0.3	0.7*	0.7	0.9	0.7	0.9	0.6*	0.9

Note. Months where the range of values for the three regions exceeds 1.5 are marked with an asterisk.

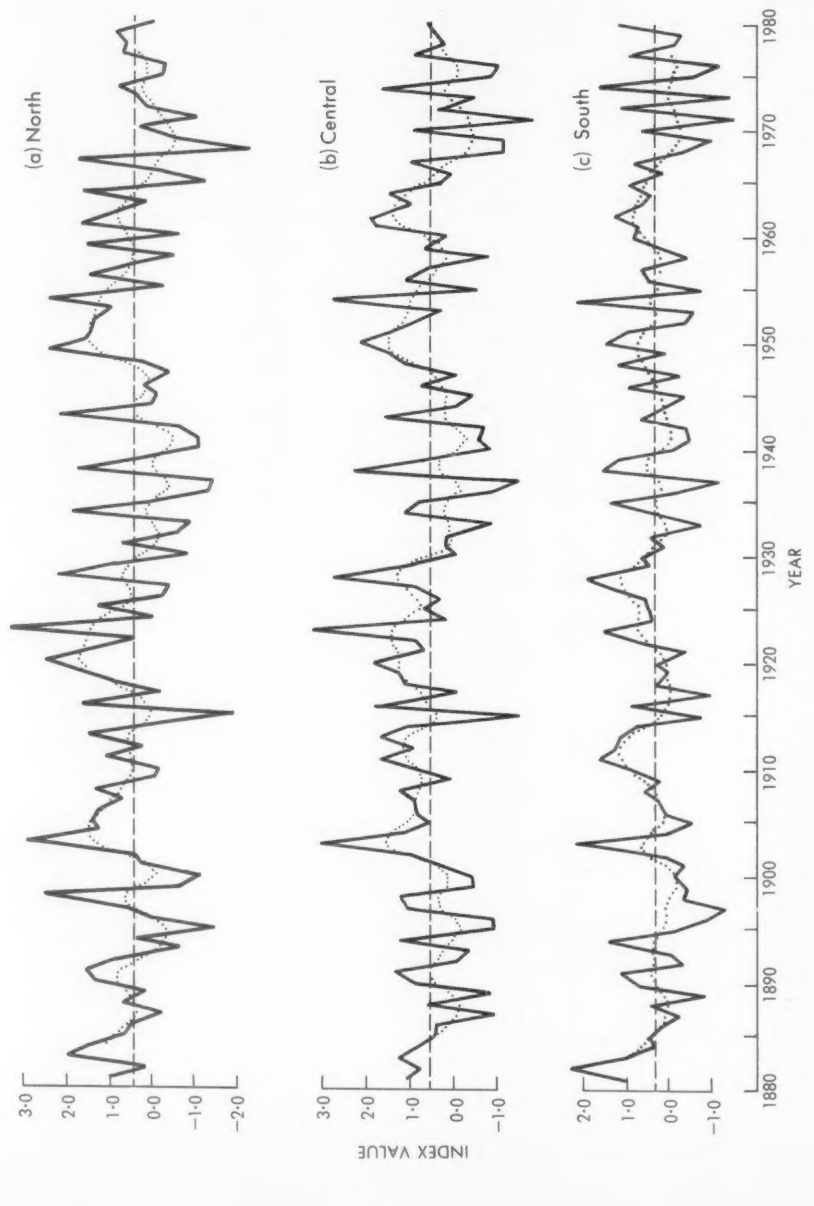

Figure 7. Annual means of the estimated values of the index of windiness (full lines), seven-year weighted running means (dotted lines) and 1881–1980 mean (dashed lines), all three regions.

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Appendix

Derivation of daily wind speed from surface pressures

Let A, B, C, . . . denote the surface pressures (mb) at midnight or midday which are available for the grid points as indicated:

Latitude	Longitude 10°W	0°	10°E
65°N	A	B	C
60°N	D	E	F
55°N	G	H	I
50°N	J	K	L
45°N	M	N	O

Then, for example, to determine the daily speed at 55°N 5°W:

Westerly flow F_w along 55°N is given by

$$F_w = \tfrac{1}{2}(J + K) - \tfrac{1}{2}(D + E).$$

Southerly flow F_s along 5°W is given by

$$F_s = 1.74 \;\{\tfrac{1}{4}(E + 2H + K) - \tfrac{1}{4}(D + 2G + J)\}$$

Resultant daily speed at 55°N 5°W = $(F_w{}^2 + F_s{}^2)^{1/2} \times 1.2$ kn.

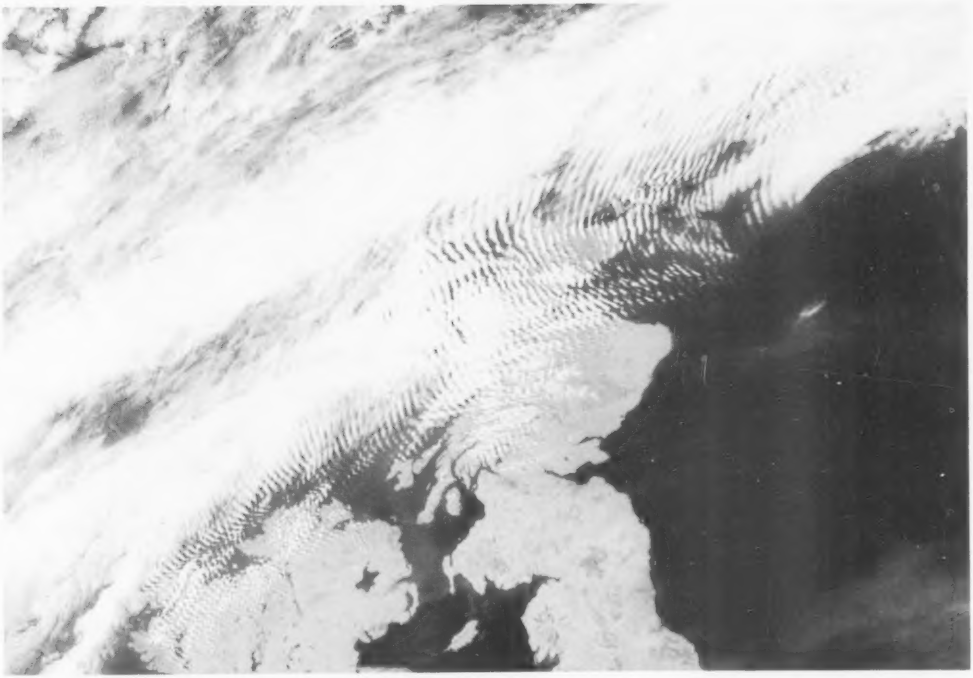
Similar expressions hold for the speed at the other five grid points shown in Fig. 6.

Notes and news

Cloud patterns observed by satellite on 26 March 1982

At 1435 GMT on 26 March 1982 the polar orbiting satellite NOAA-7 showed a remarkable series of regularly spaced cloud undulations running from north-west Ireland across north Scotland and out over the North Sea (Figs 1 and 2). The synoptic situation is shown in Fig. 3; there was little change of wind direction with height and the upper-air charts largely reproduce the pattern of the sea-level flow. Ascents for Stornoway and Lerwick are shown in Fig. 4. The wavelength of the undulations as measured from the photographs is about 10 km, and an estimate by Caswell's method* of the expected wavelength of standing waves yields a figure of 11 km.

* *Meteorol Mag*, **95**, 68–80, 1966



Photograph by courtesy of Dundee University.

Figure 1. Visual image received from NOAA-7 at 1435, 26 March 1982.

It is, of course, impossible to tell from Figs 1 and 2 whether the undulations are moving or stationary. Telephone enquiries to the Senior Meteorological Officer at RAF Kinloss revealed that no special observations were recorded in the Moray Firth area that afternoon, but apparently wave and billow clouds are so common in that part of Scotland that nothing is normally entered in the 'Remarks' column of the register about them.

Note also the condensation trails, shown as shadows on the cloud in Fig. 1, and directly in Fig. 2.

25 years ago

The Meteorological Magazine for September 1957 contained an obituary written by Mr Ernest Gold of R. G. K. Lempfert who had the distinction of being the first man with high scientific qualifications ever to be appointed to the staff of the Meteorological Office. (The Directors—more recently Directors-General—have of course all been distinguished scientists from the days of Admiral FitzRoy onwards, and all except one have been Fellows of the Royal Society.) Mr Gold quotes Sir Napier Shaw's words that until 1902 'one of the peculiarities of the Meteorological Office as a scientific establishment was that none of the members of the staff had had any preliminary scientific training'. Lempfert had graduated

Photograph by courtesy of Dundee University.

Figure 2. Infra-red image from NOAA-7 for the same time as the visual image shown as Figure 1.

with high honours in Physics at Cambridge and for a time worked in the Cavendish Laboratory under J. J. Thompson. His appointment and those a few years later of Gold himself and Corless were amply justified by results as regards both their own scientific work and their influence on policy and administration; this was the beginning of the process whereby the Office grew into the renowned scientific institution that it is today. The papers by Lempfert and Corless on air trajectories and trough lines, for example, led up to the work of the Norwegian school during the first World War and introduced the word 'front' as a technical term for the first time.

The same issue also contained four photographs by D. W. S. Limbert, taken the previous year at Halley Bay in the Antarctic while he was a member of the Royal Society Expedition of the International Geophysical Year; they include one illustrating the midnight sun.

50 years ago

The Meteorological Magazine for September 1932 contained a good deal of information about the heat wave of the previous month which had been the warmest August over much of England since 1911; the nights were particularly warm, Lympne recording a minimum of 73°F on the 20th. There were

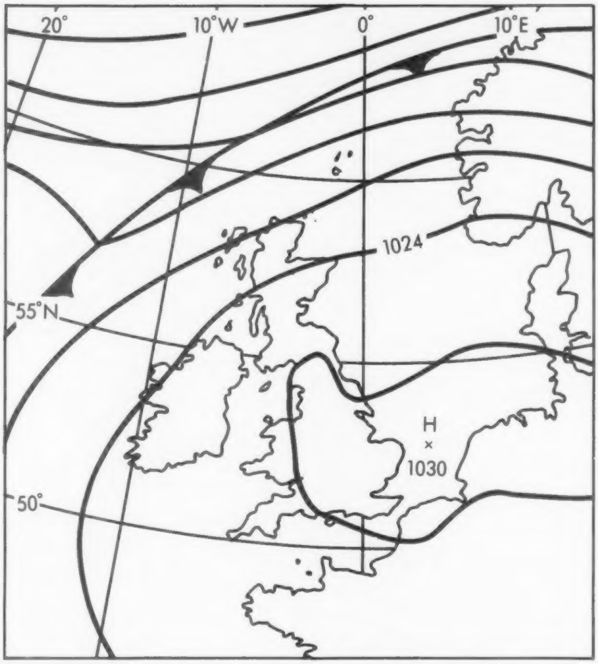


Figure 3. Synoptic situation at 12 GMT on 26 March 1982.

several heavy thunderstorms, and the effect of one of these was described graphically in the same issue by Mr E. L. Hawke, the well-known writer on meteorological matters who was Superintendent of the weather station of the Hampstead Scientific Society at the time, and was an Honorary Secretary of the Royal Meteorological Society from 1935 to 1949. Mr Hawke lived in Rickmansworth, and his account includes the following passage:

For the second time within three weeks, the Rickmansworth and Chorley Wood district of Hertfordshire was visited by a thunderstorm of unusual severity early on Friday, August 12th. The storm approached rapidly from south-south-west over an easterly surface wind, breaking, it is believed, after only a single preliminary thunderclap. Increasingly heavy rain began at 4h. 55m. G.M.T., and from 5h. until 5h. 30m. the fall maintained a persistence of intensity unparalleled in the writer's twenty-seven years' experience of meteorological observing in England and abroad.

After about 5h. 2m. the deluge was accompanied by nearly continuous hail. The stones were spheroidal, and appeared to average 0.5in. in diameter, but were in some instances amalgamated into masses approximately the size of a golf ball. To save the radiation thermometers from destruction, a journey that will not readily be forgotten was made to the instrument enclosure at 5h. 5m. The assault of ice and water can only be described as terrific. At 5h. 30m. the hail ceased abruptly, and there was a progressive slackening of the rain. By 5h. 40m., when the gauge was examined, the fall was over, except for 0.01in. The measurement for the 45 minutes from 4h. 55m. to 5h. 40m. was 2.24in.—an amount that may well have been short of the true figure by reason of the hailstones rebounding from the funnel of the gauge. Both before 5h. and after 5h. 30m. the rain was not of outstanding violence, and it is estimated that of the measured total of 2.25in. yielded by the storm, nearly, if not quite, 2in. must have fallen within the half-hour.

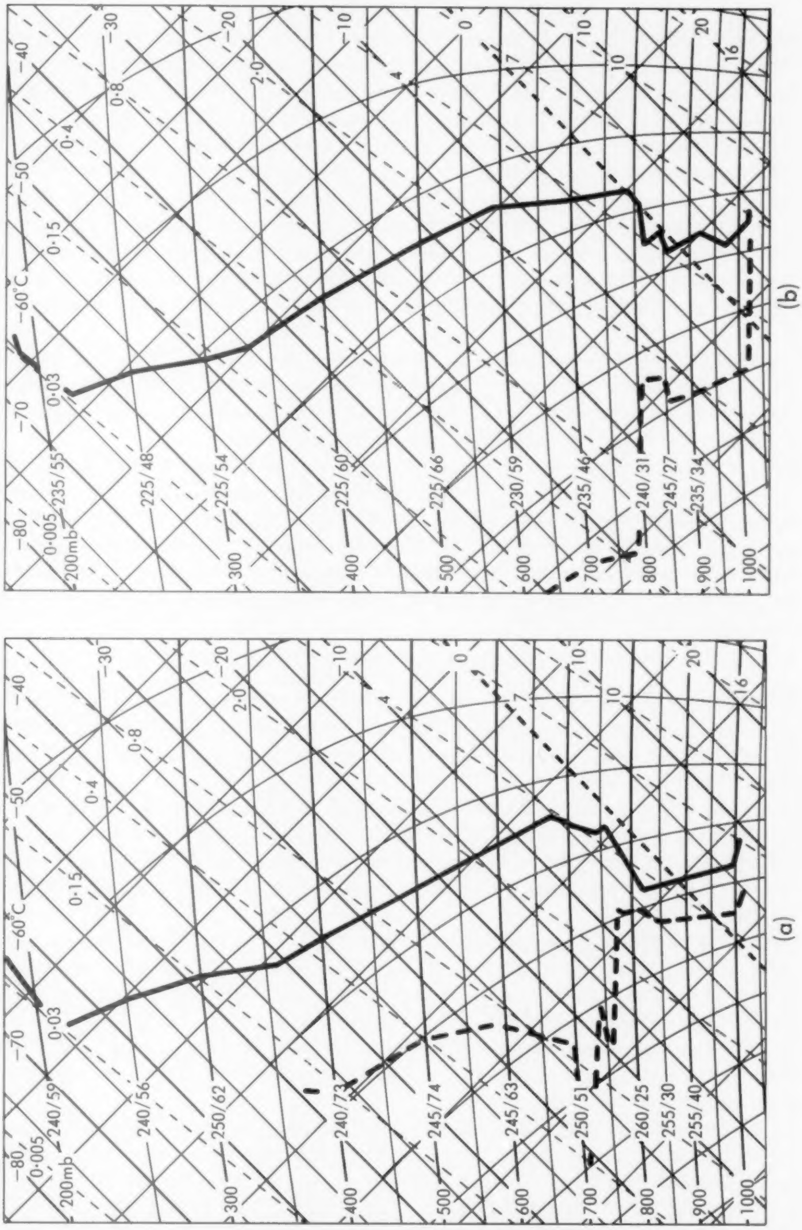


Figure 4. Tephigrams for (a) Lerwick and (b) Stornoway, 12 GMT on 26 March 1982.

Mr C. K. M. Douglas

Mr C. K. M. Douglas, O.B.E., A.F.C., B.A. died on 19 February 1982 in his 89th year. By the time of his retirement* from the Meteorological Office in 1954 he had become an almost legendary figure among forecasters. He was certainly the greatest weather forecaster of his generation in the United Kingdom, and quite possibly of all time. No one else has combined his sound grasp of mathematical and physical theory with such immense synoptic experience; his memory of individual occasions was extraordinary and all forecasters who worked with him could give examples. During the Second World War he was a Senior Forecaster in the Forecast Division at Dunstable where as one of the 'back-room boys' he was a regular and respected participant in the daily operational forecasting conferences by telephone. His assessment of the weather situation and its probable developments played a large part in the preparation of the forecasts for the D-day operation in 1944, as has been described by the late J. M. Stagg (1971);† his contribution was acknowledged by General Eisenhower in a personal letter of thanks.

He began his independent meteorological investigations before he joined the Office by his pioneering work on the upper air and air-borne cloud photography while he was a pilot in the Royal Flying Corps. He published a large number of scientific papers and articles, both alone and in collaboration with other scientists; the Brunt–Douglas equation still finds a place in the textbooks.

A nervous affliction produced certain idiosyncrasies of behaviour which were at first a little alarming to new acquaintances, but these were soon forgotten. He was not interested in administrative matters which he would leave to others while he concentrated on what he regarded as his real work. After his retirement he moved to Beer in Devon, where from 1956 to 1973 he became a rainfall observer and made daily readings which were forwarded to the Office and published in *British Rainfall.* He was awarded both the Buchan Prize and the Hugh Robert Mill Memorial Medal and Prize of the Royal Meteorological Society.

Obituary

We regret to record the death on 7 March 1982, under particularly tragic circumstances, of Mr R. S. Hewer, Assistant Scientific Officer, at Birmingham Airport; he was working in the remote observing office, preparing for the 2100 GMT observation, when an intruder entered the building and for no apparent reason shot him at his desk.

Ray Hewer joined the office in 1949 and served at a number of RAF stations, including some old names such as Swinderby, Aston Down, Lichfield, Morton Hall and South Cerney as well as at Shawbury, Pershore and in Germany, before moving to Civil Aviation in 1961 at Liverpool. He went to Birmingham the next year, 1962, and apart from a short break between 1966 and 1969 remained there for the rest of his life.

He will be remembered most for his rather quiet, dry sense of humour and the meticulous way he carried out his work. He was one of the old school who believed that the greatest help that he could give to weather forecasting was to ensure that his observations were made with care and accuracy. His records in the *Daily Registers* at Birmingham are a testimony to the high standard he set.

Outside the office, he was very much a family man. He did not have a car but he took great pleasure in planning holiday routes by train and bus so that his wife and daughter gained the maximum benefit from their holidays all over the Continent.

Ray Hewer was a willing and co-operative colleague and will be missed much by all who worked with him; he was a stalwart of the office at Birmingham and died doing what he enjoyed most about his work—observing the weather.

*See *Meteorol Mag,* **83,** 1954, 225–226. †Stagg, J.M., 1971, Forecast for Overlord. London, Ian Allan.

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